SAE Aerospace
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# AEROSPACE MATERIAL SPECIFICATION

SAE AMS2647 REV. C

Issued 1985-04
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Superseding AMS2647B

## (R) Fluorescent Penetrant Inspection
## Aircraft and Engine Component Maintenance

RATIONALE

AMS2647C is a complete revision of this specification. Changes have been made to the previous revision to reflect the results of research studies focused on determination of optimal process parameters for FPI. In addition, three appendices were added.

1. SCOPE

1.1 Purpose

This specification details requirements and procedures for the detection of defects in aircraft and engine components during maintenance and overhaul operations.

1.1.1 This specification contains three appendices which provide additional guidance designed to supplement the information contained in the main body of the document. Because the guidance contained in the appendices is either subjective in nature or may have alternative acceptable approaches, it is not intended to be binding unless specifically invoked by the cognizant engineering organization (CEO), an original equipment manufacturer (OEM), or other contractual agreement. Personnel performing inspections to this specification should be familiar with the guidance and exercise good judgment if variance from this guidance is necessary. The following appendices are included:

1.1.1.1 Appendix A – Guidelines for Design, Procurement and/or Fabrication of Penetrant Systems

1.1.1.2 Appendix B – Guidelines for Assessment of Background Fluorescence

1.1.1.3 Appendix C –Processing and Inspection of Drum Rotors/Deep Well Spools and Other Complex Parts w/Limited Accessibility

1.2 Processing of parts and interpretation and evaluation of indications revealed by this inspection process shall be accomplished by qualified personnel having experience with fluorescent penetrant inspection. Qualification of personnel shall be in accordance with ATA 105, MIL-STD-410, NAS 410, EN 4179, or ASNT SNT-TC-1A.





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1.3 Basis of Application

This process has been used typically by maintenance and overhaul facilities to inspect aircraft and engine components and associated accessories when fluorescent penetrant inspection is specified, but usage is not limited to such applications.

1.3.1 There are areas in this document that may require specific direction from the OEM or CEO. This direction shall be provided in the part material specification for each part (See 7.2.48) in the following areas:

1.3.1.1 Etching Requirements

If not specified, etching will not be performed (See 3.3.6).

1.3.1.2 Cleaning Requirements

If not specified, solvent cleaning using Alcohol, Acetone or Methyl Ethyl Ketone (where locally approved) (See 3.4) or an approved QPL-AMS-2644 solvent cleaner/remover is acceptable.

1.3.1.3 Surface Coating Removal

If not specified, parts may be inspected with the surface coating intact (See 3.3.4 and 3.3.4.1).

1.3.1.4 Penetrant Sensitivity Level

If not specified, Sensitivity Level 3 penetrants shall be used on all airframe hardware and components and Sensitivity Level 4 penetrants shall be used on all Major Rotating components of engines and Auxiliary Power Units (See 7.2.29).

1.3.1.5 Penetrant Method

If not specified, Type I, Methods A, C, or D may be used except for major rotating engine hardware which shall only be inspected using Type I, Methods C or D.

1.3.1.6 Drying

If not specified, air-circulating oven drying shall be used. If other heat-assisted drying methods are used, they shall be approved by the CEO.

1.3.1.7 Developer

If not specified, dry developer (form a) shall be used.

1.3.1.8 Inspection Coverage

If not specified, the areas described in 3.4.12.1 shall be inspected. If inspection of areas requiring special equipment or techniques (i.e., UV borescopes or light sources, special material application or removal devices, part handling fixtures, part masking, etc.) is necessary, detailed instructions shall be provided by the OEM part or material specification. When specific areas of parts require intensified inspection scrutiny, due to either their critical nature or past history of failure, this information shall be included in the repair or inspection manual or document.

1.3.1.9 Post-Inspection Cleaning

If not specified, parts shall be cleaned and dried after inspection to remove inspection residue which may be detrimental to subsequent operations or impair the structural or functional integrity of the part.

1.3.1.10 Processing Parameters

Shall be as specified within this document. If approved by the OEM, different processing parameters, other than those specified herein, may be used.

1.3.1.11 Acceptance Criteria

This specification does not provide accept/reject criteria for specific components. Where no accept/reject criteria are specified by the CEO, all relevant indications shall be regarded as suspect and shall not be accepted without review by the CEO.

1.4 Classification of Penetrant Systems

1.4.1 Applicable fluorescent penetrant systems are classified into the following Types, Methods, and Sensitivity Levels:

Type I - Fluorescent dye
Type II – Visible Dye (not applicable to this specification)

Method A: Water-Washable
Method B: Post-Emulsifiable, Lipophilic
Method C: Solvent Removable
Method D: Post-Emulsifiable, Hydrophilic

Sensitivity Level 2: Medium
Sensitivity Level 3: High
Sensitivity Level 4: Ultra-high

1.4.2 Applicable developers are classified into four forms:

Form a Dry Powder Developer
Form b Aqueous Soluble Developer
Form c Aqueous Suspendable Developer
Form d Nonaqueous Wet Developer (NAWD)

1.5 Safety – Hazardous Materials

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

1.5.1 Safety Precautions

Protective clothing, including eye shields, suitable gloves, and aprons should be worn when filling tanks or when there is a possibility of splashing or overspray. Tanks should be covered when not in use and should be operated with adequate ventilation for fume extraction. Operating instructions from the manufacturer of the system employed together with local workshop regulations shall be followed.

2. APPLICABLE DOCUMENTS

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AMS2644 Inspection Material, Penetrant

ARP1917 Clarification of Terms Used in Aerospace Metals Specifications

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E 1417 Standard Practice for Liquid Penetrant Testing
ASTM E 1135 Standard Test Method for Comparing the Brightness of Fluorescent Penetrants
ASTM E 2297 Standard Guide for Use of UV-A and Visible Light Sources and Meters used in the Liquid Penetrant and Magnetic Particle Methods

2.3 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification
QPL-AMS-2644 Inspection Material, Penetrant

2.4 ATA Specifications

Available from Air Transport Association of America, 1301 Pennsylvania Avenue, NW – Suite 1100, Washington, DC 20004-1707, Tel: 202-626-4000, www.airlines.org.

ATA Specification 105Guidelines for Training/Qualifying Personnel in Non-Destructive Testing Methods

2.5 AIA Specifications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

NAS 410 Certification and Qualification of Nondestructive Test Personnel

2.6 ASNT Documents

Available from American Society for Nondestructive Testing, P.O. Box 28518, 1711 Arlingate Lane, Columbus, OH 43228-0518, 800-222-2768 (inside U.S. and Canada), 614-274-6003 (outside USA), www.asnt.org.

SNT-TC-1A Recommended Practice for Personnel Qualification in Nondestructive Testing

2.7 EN Documents

Available from the British Standards Institute, 389 Chiswick High Road, London, W4 4AL, United Kingdom, +44 (0)20 8996 9001, www.bsi-global.com.

BS EN 4179 Qualification and approval of personnel for non-destructive testing

## 3. TECHNICAL REQUIREMENTS

### 3.1 Materials

Materials used (i.e., penetrants, emulsifiers, and developers) shall conform to AMS2644 and be listed in QPL-AMS-2644, and be approved by the original equipment manufacturer's (OEMs) part or material specifications.

#### 3.1.1 Grouping of Materials

Penetrants and their emulsifiers shall be qualified and used as a "penetrant/emulsifier" system, furnished by one manufacturer to perform a specific method or process of penetrant inspection. Method A penetrants are not qualified with an emulsifier. Developers may be from a different manufacturer.

### 3.2 Equipment

Equipment shall be constructed and arranged to permit uniform, controlled operation. Quality control of equipment shall be as specified in Section 4.

NOTE: Guidelines available for use in design, procurement and/or fabrication of penetrant inspection equipment are contained in Appendix A.

### 3.3 Surface Preparation of Parts to be Inspected

Proper surface preparation of parts for penetrant inspection is extremely critical. The primary objectives of part preparation are to insure the discontinuity is clean, dry and open to the surface and that minimal fluorescent background is obtained after processing. Surface preparation, including cleaning, stripping, masking, blasting, peening, etching and drying, shall be accomplished using methods and materials specified in the OEM's part or material specifications. If OEM guidance is not provided, the information in the following paragraphs shall be considered by the CEO in establishing requirements to prepare parts for inspection.

CAUTION: Visible or contrast dye penetrant shall not be used on a part prior to fluorescent penetrant inspection (FPI). Contamination from the visible dye can severely degrade the brightness of the fluorescent dyes.

#### 3.3.1 General

Reliable penetrant inspections are highly dependent on proper pre-inspection processing. Because this is difficult or impossible for inspection personnel to determine or control, it is the responsibility of the CEO to include proper pre-inspection processing requirements in all work documents specifying the use of penetrant inspection. As a rule, any operation, which may prevent penetrant from entering defects, shall be avoided.

3.3.1.1 Personnel accomplishing surface preparation such as cleaning shall be properly trained so that they are fully knowledgeable with the operations they are performing, including both company and OEM specifications. They should also be aware of the impact that improper performance of their duties can have on both hardware and on subsequent operations such as fluorescent penetrant inspection (FPI).

CAUTION: Failure to properly clean parts prior to FPI can prevent the detection of flaws which could ultimately result in property damage, loss of aircraft, and/or loss of life.

3.3.2 Sequence of operations shall be as follows:

3.3.2.1 Penetrant inspection shall be performed prior to any operation (such as plating, anodizing or cold working) which may close or smear openings or leave unremovable residue within a defect.

3.3.3 Penetrant inspection shall be performed subsequent to any operation (such as heat treatment involving quenching, welding, cold forming, or grinding) that may introduce or expose defects.

3.3.4 Cleaning

Areas of parts to be examined shall be free of moisture, grease, oil, grinding compounds, rust, scale, acids or alkalis, fluxes, burrs, feather edges, paint (primer, enamel), and other foreign materials which could hide defects or produce irrelevant indications that may interfere with the examination process. It is the responsibility of both cleaning and inspection personnel to visually assess cleanliness for suitability of inspection. Guidance on assessing the level of background fluorescence is provided in Appendix B.

3.3.4.1 Surface cleaning and penetrant processing should be considered a continuous operation to prevent inadvertent contamination of the part. When not conducted as a continuous operation, the CEO should consider the need for special precautions to ensure parts are protected from environmental or other inadvertent contamination between cleaning and FPI processing.

3.3.4.2 Cleaning Methods

Cleaning methods chosen for a particular part shall be consistent with the type of contaminant to be removed and shall not be chemically or mechanically detrimental to the part. Potential methods include solvent cleaning, steam cleaning, ultrasonic cleaning, vapor blasting, paint and carbon stripping, and alkaline or acid cleaning. Wet glass bead blasting has been shown to be detrimental to FPI performance and its use on parts prior to FPI is not recommended[1]. Adherence to OEM recommended media blast pressures and grit sizes is critical to avoid closing of indications.

3.3.4.3 Cleaning methods shall not leave a residue, which could interfere with the FPI process or potential subsequent repair operations.

NOTE: Halogenated/chlorinated solvents shall not be used on titanium alloys.

3.3.4.4 For spot cleaning prior to FPI, surface contamination should be removed using Isopropyl Alcohol, Acetone or Methyl Ethyl Ketone (where locally approved) or an approved QPL-AMS-2644 solvent cleaner/remover. Aqueous cleaners should not be used in a field inspection or for spot cleaning because of concerns with drying the part sufficiently for effective FPI. If aqueous cleaners are used, parts must be dried with an approved drying method.

3.3.5 Plating or Surface Coatings

Coatings or surface treatments can prevent penetrant from entering defects as well as cause varying levels of fluorescent background on the part. High background fluorescence reduces the contrast between indications and background (signal to noise ratio) with a corresponding decrease in inspection sensitivity. With certain types of plating or coating, it may be possible to perform an adequate inspection providing the plating or coating is in good condition and the defect is open to the surface.

3.3.5.1 Conversion coatings, impregnations, flame spray, plating or paint should be removed prior to penetrant inspection if an inspection with a high level of sensitivity is desired. Removal of these coatings shall be specified in the work document. If not specified, it will be assumed that inspections are to be conducted with the coating intact. Removal of these coatings should not be done in a manner which may cause metal smearing, or which leaves chemical residue on the part that may contaminate defects.

3.3.6 Mechanical Surface Treatment

Surface treatment such as abrasive blasting, sanding and burnishing operations can produce a smeared surface on some materials. If it is necessary to perform any of these operations prior to penetrant inspection, it is good practice to accomplish an acid etch prior to inspection. It is recommended to follow media blasting operations with an approved process to remove remaining media. Data exists to support the use of a rinse to remove remaining media[1].



[1] "Engineering studies of cleaning and drying processes in preparation for fluorescent penetrant inspections," Lisa Brasche, Lee Clements, Anne D'Orvilliers, Keith Griffiths, William Griffiths, Pramod Khandelwal, Terry Kessler, Andy Kinney, Brian Larson, John Lively, Rick Lopez, Bill Meeker, Jeff Stevens, Kevin Smith, and Scott Vandiver, FAA Report No. DOT/FAA/AR/03/73, January 2004, available at www.faa.gov and through the National Technical Information Service (NTIS).

CAUTION: When employing one of the above surface treatments, it is important to follow the approved parameters, consumable materials and procedures as specified by the OEM's specification for the particular part.

3.3.6.1 Peening operations shall not be performed prior to penetrant application because the smearing and compressive stresses imparted by peening can completely eliminate the possibility of penetrant from entering a discontinuity.

3.3.7 Chemical Surface Treatment

Chemical surface treatments such as etching can be detrimental to part function or serviceability. It is the responsibility of the CEO to make this determination and act accordingly. If the repair or overhaul document does not specify acid etch prior to inspection, it will not be accomplished. In all cases, only approved etching (cleaning) procedures and consumable materials specified by the OEM's engine manuals for a specific part shall be permitted.

3.3.8 Drying

Parts shall be fully dry before application of penetrant. Failure to sufficiently dry a part after cleaning can affect the capillary action and prevent the penetrant from entering a flaw. Parts cleaned with an aqueous or slow drying solvent cleaner shall be dried in accordance with OEM requirements. If not specified, parts may be "flashed dried" and/or dried at an elevated temperature to remove moisture from the part surface and possible discontinuities.

CAUTION: Drying times will depend upon the number of parts and the size and mass of the part being heated. Pooled or trapped water will prevent proper drying. If moisture remains on a part surface, the drying process shall be repeated.

3.3.8.1 Flash dry parts by submerging the part in a tank of hot water or by hot water spraying. With either method, the water shall be heated to 66 to 93 °C (150 to 200 °F) and the part shall dwell (i.e., remain submerged or sprayed) until the temperature of the part reaches the water temperature. Remove the part from the tank and remove excess water by draining, repositioning, suction, blotting with a clean absorbent material, or by blowing off with an oil filtered and water filtered shop air gun. Proper flash drying is indicated by seeing the water on the surface of a part start to "flash" or "whisk" off as the part is being removed from the hot water tank.

3.3.8.2 Air dry parts by placing the part in an oven or hot air dryer. There shall be no significant pooling of water prior to placing the part in the oven or hot air dryer. If necessary, utilize repositioning, suction, blotting with clean absorbent material, or air blowing with filtered (oil and water) shop air to remove excess water. Unless otherwise specified, the oven temperature shall be between 71 to 121 °C (160 to 250 °F), to remove moisture. Parts shall remain in the oven for a minimum of 1 hour or for 10 minutes after the surface of the part reaches a minimum of 66 °C (150 °F).

3.3.8.2.1 Where single parts and/or batches of parts having approximately the same mass/surface area are processed through the oven or hot air dryer, drying times may be established by sampling surface temperatures of representative parts. Sampling must be repeated for different oven/hot air dryer configurations or if nominal oven drying temperatures are changed. If sampling is used, a log of drying times for each part or group of parts must be maintained.

3.3.9 Masking

Parts inspected using the penetrant method shall be inspected over all visibly accessible surfaces except that parts having riveted doublers, data plates, air seals, rubberized coatings or other areas which may entrap penetrant and which are not removed as part of the normal process will not receive inspection in the areas where excessive bleed out of the penetrant prohibits it. If inspections of these areas are required, removal and/or masking shall be specified in the applicable repair or inspection document.

3.3.9.1 Removal of anti-friction bearings prior to penetrant inspection is recommended. If bearings are not removed, they should be completely masked prior to routing to FPI in order to prevent contamination by penetrant fluid.

3.4 Processing Procedures

Descriptions of the different processing procedures are presented in Figures 1, 2, 3, and 4. When invoked, Appendix C contains requirements for processing parts with complex geometry and/or limited access.

3.4.1 Visual Examination

Visually examine parts. Parts to be processed/inspected shall be clean, dry and free of surface contaminants. Surface contamination can interfere with the capillary action of the penetrant and prevent the penetrant fluid from being drawn into a surface discontinuity, thus compromising the FPI results. The goal is to get parts clean enough to perform a reliable inspection. Parts shall not be processed if they are considered insufficiently clean for FPI.

3.4.1.1 If contaminants (grease, oil, loose soils, etc.) can be removed with your finger or if the part has scale (hardened deposits), then the part is not sufficiently clean. Reclean the part until acceptable (ref. 3.3)

Note: If necessary, localized surface contamination may be removed using Isopropyl Alcohol, Acetone or Methyl Ethyl Ketone (where locally approved) or an approved QPL-AMS-2644 solvent cleaner/remover if the contaminant is amenable to this type of cleaning method.

3.4.1.2 Parts which show visible evidence or are suspected of having been contaminated with visible (contrast) dye penetrant shall be thoroughly cleaned to remove all traces of contamination as these dyes can severely degrade the brightness of the fluorescent penetrant. Use of visible dye penetrant is not recommended for aerospace components.

3.4.1.3 Use of a black light during initial examination may help to identify the presence of contaminants. Many organic contaminants fluoresce blue under UV light.

3.4.1.4 The use of one higher penetrant sensitivity level from that sensitivity level specified for a given part is permissible.

3.4.2 Penetrant Application for Methods A, B, C, and D

3.4.2.1 Water washable (Method A) and post-emulsifiable lipophilic (Method B) penetrant shall not be used on major rotating engine components (e.g., disks, hubs, spools, rotors, major rotating seals and spacers, etc.).

3.4.2.2 Prior to penetrant application, the penetrant and part's surface temperature shall be within the range of 4 to 52 °C (40 to 125 °F). If the surface of the part is cool to the touch, it shall be considered to be below 52 °C (125 °F).

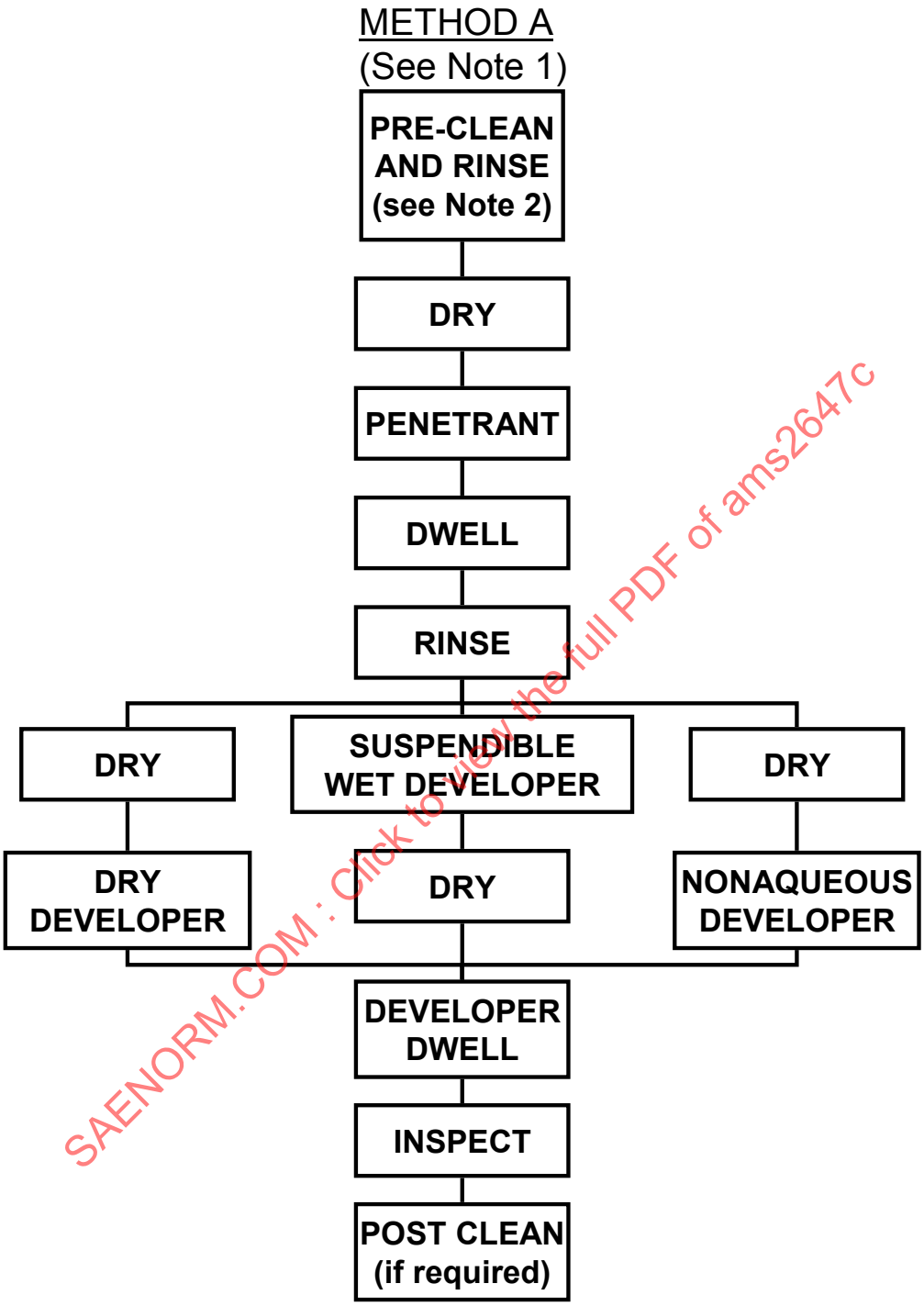
3.4.2.3 Penetrant shall be applied by spray, immersion or brushing to provide penetrant coverage as required. Check for complete penetrant coverage with a black light.

3.4.2.4 If the penetrant beads up or separates when the penetrant is applied to the surface of the part, the part was not clean enough and shall be recleaned.

3.4.2.5 Use not less than 20 minutes penetrant dwell/drain time.

3.4.2.6 Draining can be carried out by suspension of a part over the immersion tank. If penetrant is drained into a separate drip tray, the penetrant may not be reused unless the drip tray is covered when not in use or the penetrant is re-checked in accordance with 4.5.1.

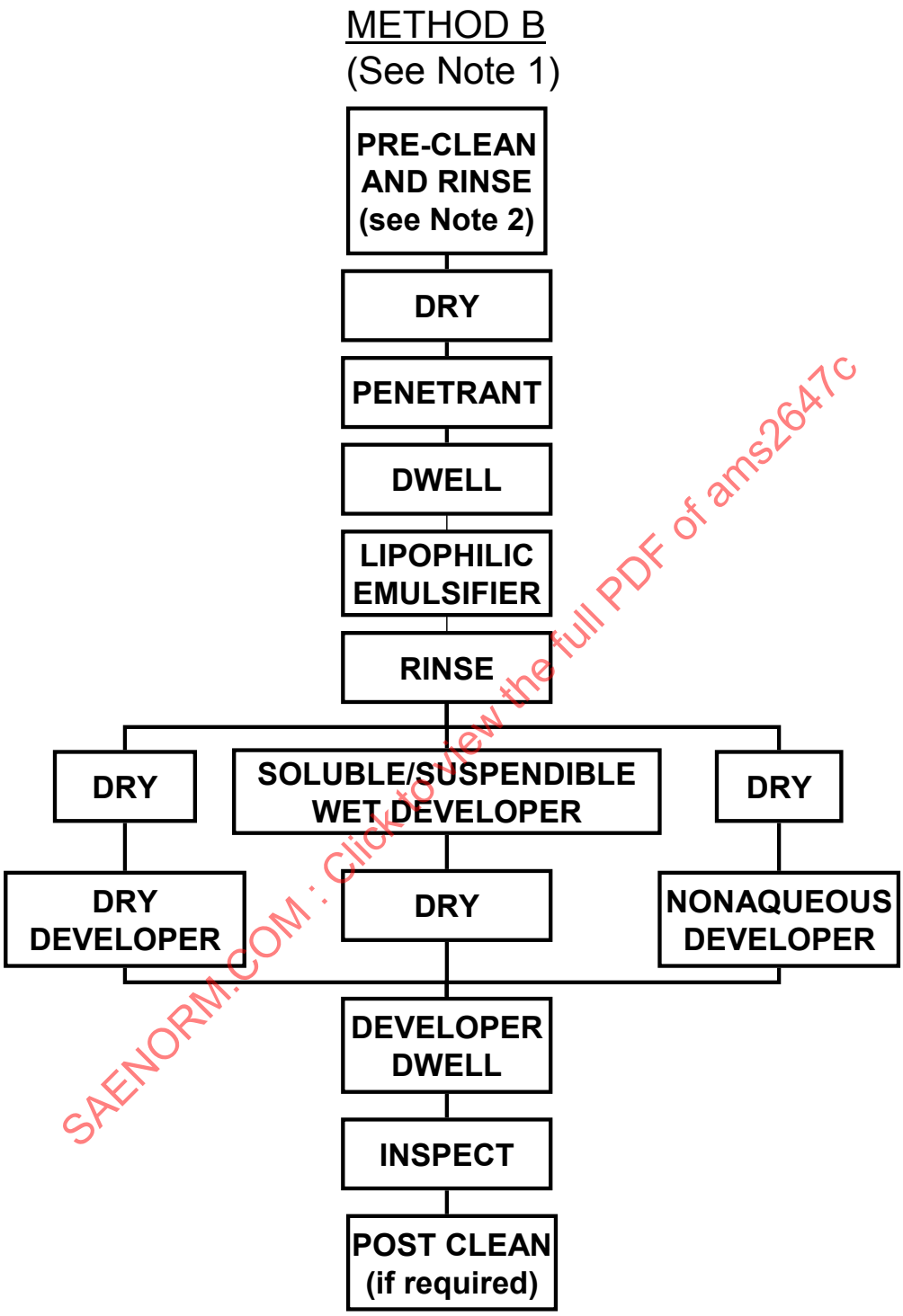
3.4.2.7 Parts left to dwell longer than 2 hours shall have penetrant reapplied to rewet the part.






NOTE 1. Method A should not be used on major engine rotating components unless otherwise approved by the hardware or component manufacturer.
NOTE 2. Etch may be required to remove smeared metal. Consult part or material specification.

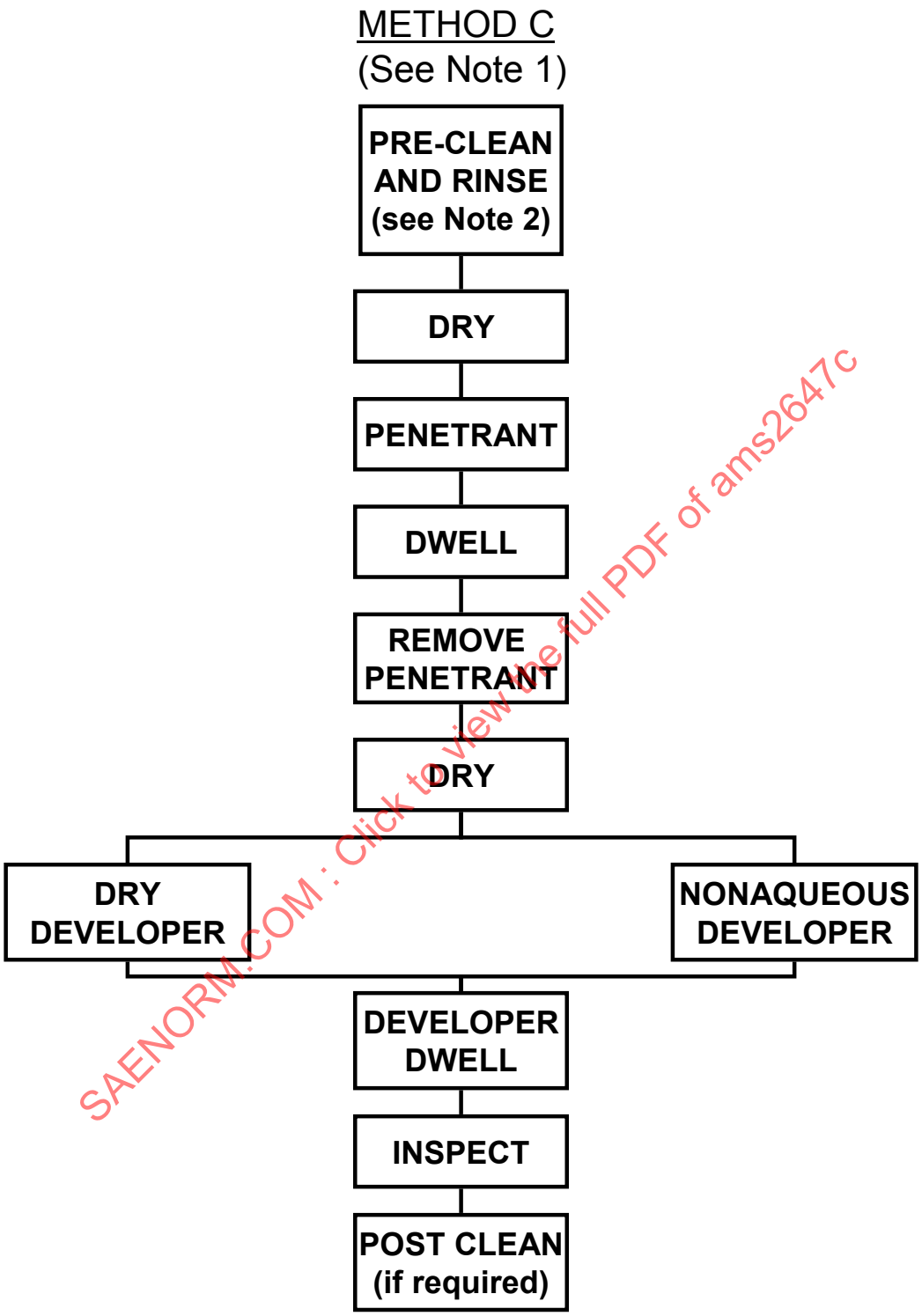
FIGURE 1 - WATER WASHABLE PENETRANT INSPECTION PROCESS






NOTE 1. Method B is not applicable to engine parts.
NOTE 2. Etch may be required to remove smeared metal. Consult part or material specification.

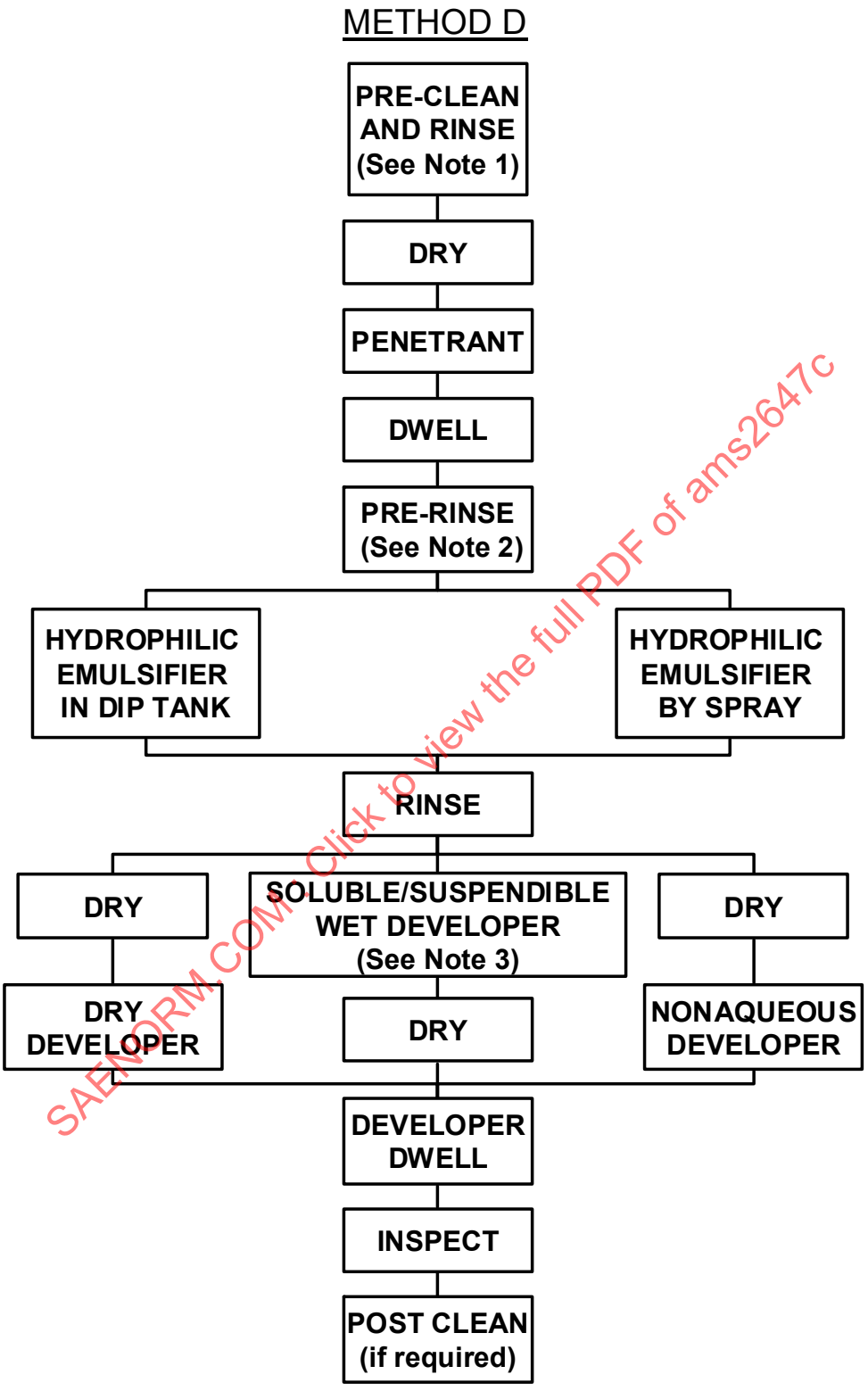
FIGURE 2 - POST-EMULSIFIABLE (LIPOPHILIC) PENETRANT INSPECTION PROCESS






NOTE 1. Method C is for localized areas only..
NOTE 2. Etch may be required to remove smeared metal. Consult part or material specification.

FIGURE 3 - SOLVENT REMOVABLE PENETRANT INSPECTION PROCESS






NOTE 1. Etch may be required to remove smeared metal. Consult part or material specification.
NOTE 2. Pre-rinse is not required prior to spray emulsification.
NOTE 3. Soluble wet developer is not permissible for use on engine parts.

FIGURE 4 - POST-EMULSIFIABLE (HYDROPHILIC) PENETRANT INSPECTION PROCESS

3.4.3 Water Washable Penetrant Removal (Method A)

3.4.3.1 Remove penetrant with a coarse spray rinse or an air agitated immersion wash tank.

3.4.3.2 Maximum water line pressure shall be 275 kPa (40 psi). Hydro-air nozzles are permitted with a maximum air line pressure of 170 kPa (25 psi).

3.4.3.3 When possible, the spray washing distance between part surface and the spray nozzle tip shall be not less than 305 mm (12 inches).

3.4.3.4 Spray or immersion washing time shall be held to a minimum. Wash time should be held to not more than 90 seconds on any one area of a part. To assure the adequacy of the wash, the washing shall be conducted under black light illumination such that the excess penetrant readily fluoresces.

3.4.3.5 Control water temperature within the range 10 to 38 °C (50 to 100 °F).

3.4.3.6 After washing, drain water from parts, utilizing repositioning, suction, blotting with clean absorbent material, or an air blow off using oil and water filtered shop air with a line pressure less than 170 kPa (25 psi) to prevent pooling.

3.4.4 Application of Lipophilic Emulsifier (Method B)

3.4.4.1 Lipophilic emulsifiers are not acceptable for aircraft engine parts.

3.4.4.2 Apply by flowing emulsifier on the part or by dipping the part in emulsifier and letting it dwell for the required time. Lipophilic emulsifiers shall not be applied by spray or brush and shall not be agitated while in contact with the surface of the part. All surfaces should receive a uniform emulsification and consistent contact time on all surfaces. For large or complex parts, parts may be processed in sections to control the emulsification process.

3.4.4.3 Contact with emulsifier shall be kept to the least possible time consistent with an acceptable background and shall not exceed 3 minutes.

3.4.5 Post-Rinse of Lipophilic Emulsifier (Method B)

3.4.5.1 Water spray or immerse parts to remove emulsified penetrant. Maximum spray or immersion time should be held to 90 seconds on any one area of a part.

3.4.5.2 Washing shall take place in a suitably darkened area under black light to confirm removal of fluorescent background.

3.4.5.3 After rinsing, drain water from parts utilizing repositioning, suction, blotting with a clean absorbent material, or an air blow off using oil and water filtered shop air at less than 170 kPa (25 psi) line pressure to prevent pooling.

3.4.5.4 Control water temperature within a range of 10 to 38 °C (50 to 100 °F). Manual spray shall be controlled such that adequate washing occurs with a maximum pressure of 275 kPa (40 psi). Automated spray parameters shall be controlled to prevent overwashing. Capability shall be demonstrated on known defect standards.

3.4.5.5 When possible, the spray washing distance between part surface and the tip of the spray nozzle shall not be less than 305 mm (12 inches).

3.4.6 Local Application for Solvent Removable Penetrants (Method C)

3.4.6.1 Remove the excess penetrant by wiping with a clean, lint-free, dry cloth or absorbent toweling.

3.4.6.2 Remove the remainder of the surface penetrant with a lint-free cloth or towel, dampened with a QPL-AMS-2644 approved solvent. Ensure that the surface of the part and/or the cloth or towel is not saturated with solvent. During the wiping, the part and cloth or towel shall be observed under appropriate black light illumination to ensure adequate removal of surface penetrant. Excessive removal of the surface penetrant or flooding of the solvent on the surface of the part shall require the part to be cleaned, dried, and reprocessed.

3.4.6.3 The surface of the part shall be dried by wiping with a lint-free, dry cloth or towel or by evaporation.

3.4.7 Pre-Rinse for Hydrophilic Emulsifier (Method D)

3.4.7.1 Where necessary, spray or immersion rinse parts to remove excess penetrant from the part. Spray or immersion washing time shall be held to a minimum. Wash time shall be held to not more than 90 seconds on any one area of a part. The adequacy of the wash shall be checked under black light illumination. Black lights used to monitor the wash process shall be checked to ensure that excess penetrant readily fluoresces.

NOTE: Pre-rinse may be omitted.

3.4.7.2 Allow water to drain from the part. Reposition parts as necessary to aid in draining.

3.4.7.3 If necessary, use filtered shop air with a line pressure less than 170 kPa (25 psi) or use a suction device to remove excess water from cavities.

3.4.7.4 Control water temperature within a range of 10 to 38 °C (50 to 100 °F). Manual spray shall be controlled such that adequate washing occurs with a maximum pressure of 275 kPa (40 psi). Automated spray parameters shall be controlled to prevent overwashing. Capability shall be demonstrated on known defect standards.

3.4.8 Application of Hydrophilic Emulsifier (Method D)

3.4.8.1 Application may be by spray or immersion provided that all surfaces receive a uniform emulsification and consistent contact time on all surfaces. Appendix C provides additional details on processing complex parts.

3.4.8.2 All surfaces to be inspected shall be completely covered in hydrophilic emulsifier solution during contact time.

3.4.8.3 Contact with the hydrophilic emulsifier shall be kept to the least possible time consistent with an acceptable background and shall not exceed 2 minutes.

3.4.8.4 In immersion systems, hydrophilic emulsifier and/or part shall be mildly agitated. If air or mechanical agitation is used, it shall produce no more than a thin layer of bubbles on the surface of the solution.

3.4.8.5 For immersion application, the concentration of the emulsifier solution shall be in accordance with 4.5.2.2.

3.4.8.6 For spray application, the concentration of the emulsifier solution shall be in accordance with 4.5.2.3.

3.4.9 Post-Rinse of Hydrophilic Emulsifier (Method D)

3.4.9.1 Hydrophilic emulsifier may be removed by spray rinsing or by immersing the part in a water-filled, air-agitated tank followed by a spray touch-up rinse, provided that all surfaces receive a uniform rinse and consistent contact time on all surfaces. For large or complex parts, parts may be processed in sections to control the rinse process.

3.4.9.2 Water temperature shall be controlled within a range of 10 to 38 °C (50 to 100 °F). Manual spray shall be controlled such that adequate washing occurs with a maximum pressure of 275 kPa (40 psi). Automated spray parameters shall be controlled to prevent overwashing. Capability shall be demonstrated on known defect standards.

3.4.9.3 When possible, distance between part surface and the spray nozzle tip shall be not less than 305 mm (12 inches).

3.4.9.4 Final rinse time should be held to the minimum required to remove excess penetrant from the part. Rinse time should be held to not more than 90 seconds on any one area of a part.

3.4.9.5 After rinsing, drain water from parts utilizing repositioning, suction, blotting with a clean absorbent material, or an air blow off using oil filtered and water filtered shop air at less than 170 kPa (25 psi) line pressure to remove excess water and thus prevent pooling.

3.4.10 Drying for Method A, B, and D

3.4.10.1 If oven drying is used, oven temperature shall not exceed 71 °C (160 °F) (See 4.7.1). If hot air guns are used, they shall be approved by the CEO. Oven time shall be measured from the point at which the oven achieves normal operating temperature. Use minimum drying time to completely dry parts. Parts shall be checked for dryness at no greater than 20 minute intervals. Penetrants are subject to heat fade if left in the oven too long.

3.4.11 Developing

3.4.11.1 Use dry developer except where aqueous soluble/suspendable or nonaqueous wet developer (NAWD) is specified.

3.4.11.2 Developer shall be applied within 2 hours of penetrant removal to prevent excessive bleed-out.

3.4.11.3 Parts shall not be exposed to black light radiation in excess of 1000 microwatts/cm$^2$ at the part surface while developing.

3.4.11.4 Allow part to develop for not less than 10 minutes before inspection.

3.4.11.5 Dry Developers can be used on Methods A, B, C, and D penetrants. Ensure parts are dry before applying developer.

3.4.11.5.1 Visually examine all surfaces to be inspected under adequate lighting to ensure complete developer coverage. Studies have shown that cracks facing up in the developer dust cloud chambers have a higher brightness than cracks facing down or sideways[2]. Care shall be taken in loading parts into baskets, carriers, etc. such that developer coverage is adequate for all surfaces and is not blocked by fixtures.

3.4.11.5.2 Apply dry developer to a dry part so that all areas to be inspected are completely covered with a light coating of developer. In contrast to NAWD, application of excess dry developer and subsequent removal is preferred to application of a coating that is too light. Note that developer application to all surfaces to be inspected may require additional steps to ensure that the underside and/or the sides of parts receive adequate coverage. For cloud chamber configurations, this may be accomplished subsequent to the chamber application using a bulb or spray wand to provide assess to inadequately covered surfaces. Handling fixtures and containers may also block developer application. Supplemental developer application may be needed.



[2] Brasche, L., Lopez, R., and Eisenmann, D., "Dry Developer," Proceedings of the Review of Progress in Quantitative NDE, vol. 23 a, 2006.

3.4.11.5.3 Part surface should be visible through the developer layer. Excessive powder may be removed prior to inspection. This may be accomplished by blowing with dry air at pressure not greater than 35 kPa (5 psi).

3.4.11.5.4 Parts shall be cleaned and reprocessed if time after development exceeds 4 hours.

3.4.11.6 Nonaqueous Wet Developers (NAWD) can be used on Methods A, B, C, and D. NAWD should only be used when specified by the CEO or as an evaluation aid after inspections have been competed using the primary developer. Ensure parts are dry before applying developer to part.

3.4.11.6.1 When NAWD is used, apply the developer, by spray only, to a dry part at touch temperature and with frequent agitation of the suspension. The spray should generally be held 6 to 12 inches from the surface of the part such that the developer goes on wet and dries to a whitish haze.

3.4.11.6.2 When using NAWD, surface coverage is very important and should be carefully controlled. Too light a coating will not provide sufficient development while too heavy a coating may mask defect indications.

3.4.11.6.3 An adequate coating has a whitish appearance, yet the metallic surface background remains visible. If too heavy a coating is applied such that no metallic background is visible, parts shall be recleaned, dried, and reprocessed.

3.4.11.6.4 Allow parts to develop for a minimum of 10 minutes. When NAWD is being used as an evaluation aid, inspection should take place immediately after application and again after the minimum developer dwell time (10 minutes). This is done to prevent confusion due to excessive bleed out and diffusion of indications.

3.4.11.6.5 Parts shall be inspected within 1 hour of developing. Parts shall be recleaned, dried, and reprocessed if time after developing exceeds 1 hour.

3.4.11.7 Soluble (form b) and Suspendable (form c) Aqueous Developers can be used on Penetrant Methods B, and D. Soluble aqueous developers (form b) are not acceptable for use in conjunction with water washable penetrants (Method A).

3.4.11.7.1 Soluble aqueous developer shall be completely dissolved. Concentrations shall be in accordance with manufacturer's instructions.

3.4.11.7.2 Developers shall be applied by spray, flowing, or immersion immediately after removal of excess penetrant. Do not brush. Apply a uniform solution of developer only as necessary to wet all inspection surfaces. Avoid accumulations of developer in fillets, recesses, or crevices. Avoid prolonged contact with developer solution in order to minimize removal of penetrant from discontinuities. Dry as in 3.4.10.

3.4.11.7.3 Allow part to develop for 10 minutes after drying and before inspection.

3.4.11.7.4 Parts shall be inspected within 2 hours of developing. Parts shall be cleaned and reprocessed if time after developing exceeds 2 hours.

3.4.12 Inspection

3.4.12.1 Unless otherwise specified parts inspected in accordance with this specification are to receive complete inspection coverage except that, areas of parts having riveted doublers, data plates, rubberized or flame sprayed coatings, bushings or other items which may entrap penetrant and which are not required to be removed by the pre-inspection procedures, need not be inspected. Complete coverage refers to those areas of a part, which can be viewed using a standard handheld black light and viewing supplemented by nothing more than mirrors.

NOTE: Inspection of internal surfaces of complex parts having internal cavities with limited accessibility such as drum rotors/deep well spools requires special considerations. Appendix C provides a best practice for inspection of these components. This Appendix shall be considered and applied as appropriate when invoked by the OEM or other CEO.

3.4.12.2 Inspect parts in a booth or darkened area where ambient white light at the inspection surface(s) does not exceed 20 lux (2 footcandle maximum). Use light meter for measurement of white light.

3.4.12.3 Before beginning inspection, the individual shall wait at least one minute to adapt to darkness vision. Dark adaptation times can vary among individuals and will also depend on the level of light the eyes were previously exposed to (i.e., shop lighting versus sunlight). A gauge such as a fluorescent comparator can be used to help assess whether adequate dark adaptation has been achieved.

3.4.12.4 Use of impact resistant ultraviolet radiation blocking eyewear is strongly recommended particularly when inspecting highly reflective surfaces. Lenses that preferentially block ultraviolet and blue/violet light (wavelengths of approximately 400 nanometers and below), while transmitting all longer visible are recommended. Lenses that are photochromic, or those that are filtered to reduce luminous transmittance of visible light wavelengths un-arbitrarily, shall not be worn during inspection.

3.4.12.5 Black lights should be positioned such that glare is minimized and the area being inspected is illuminated with a minimum UV intensity of 1000 μW/cm$^2$. Surfaces shall only be illuminated for the minimum period of time needed to complete the inspection. Illumination of indications with excessive levels of UV light for an extended period of time can significantly reduce the brightness of the indications[3].

3.4.12.6 Handling of parts should be minimized and whenever possible, part handling should be limited to non-critical areas or areas that have been previously inspected.

3.4.12.7 Ensure all required inspection surfaces are examined. Use a consistent and systematic search strategy in inspecting the component and individual features such as holes and blade dovetails/fir trees. Use appropriate markers (i.e., approved marking pens and tape) on components to show where inspections started and stopped and allow for an overlap.

3.4.12.8 Fluorescent contamination or fluorescent background in the immediate area of interest should be considered an indication until evaluated and cleared.

3.4.12.8.1 If the part shows excessive fluorescent background in the inspection booth, the part was not sufficiently clean or was not processed properly. “Excessive background” is a subjective term. It is normal to see some fluorescent background on the surface of a part. However, if the fluorescent background interferes with the inspection, then the part shall be cleaned, dried and reprocessed. Refer to Appendix B for guidance on assessing background fluorescence.

3.4.12.9 Specialized visual aids (e.g., UV/white light borescopes, UV liquid light guides, magnification, UV pencil lamps, video cameras, etc.) shall be used when specified by the OEM’s part or material specification to inspect cavities or surfaces difficult to see by direct vision. Appendix C provides a detailed recommended practice for drum rotors and deep well spools which includes performance measures for specialized visual aids. .

3.4.12.10 Except as required by 3.4.12.11, specialized viewing aids (e.g., UV/white light borescopes, UV liquid light guides, UV pencil lamps, video cameras, etc.) are recommended for inspection of cavities or surfaces difficult to see by direct vision but are only required to be used when specified by the CEO or the OEM's part or material specification.

3.4.12.11 Optimum line of sight is perpendicular to the surface to be inspected. Adequate visual access can be achieved within 45 degrees of that perpendicular line of sight. Optimum visual access occurs when the line of sight is perpendicular to the surface being inspected. In areas where visual access results in a line of sight viewing angle greater than 45 degrees from a line perpendicular to the surface being inspected, or where the surface to be inspected extends beyond a depth to opening ratio greater than 1, or where other limitations prevent a valid unaided inspection, special equipment such as mirrors or borescopes, shall be considered to meet the 45 degree or greater line of sight.



[3] "UV-A Induced Fade in Fluorescent Penetrant Tests," Richard D. Lopez, Lisa J.H. Brasche, and David J. Eisenmann, The NDT Technician, published by the American Society for Nondestructive Testing, vol. 5, no. 3, July 2006.

3.4.12.12 Indications shall be investigated to verify their nature whether relevant, non-relevant, or false. Interfering fluorescent background, relevant or questionable indications may be evaluated as follows:

NOTE: This procedure may only be performed twice for any given original indication or area.

3.4.12.12.1 Lightly dampen a clean soft brush or cotton swab with clean solvent (e.g., Isopropyl Alcohol, Acetone, or Methyl Ethyl Ketone (where locally approved) etc.).

NOTE: Halogenated solvents shall not be used on titanium alloys.

3.4.12.12.2 Remove any excessive solvent from the brush or cotton swab applicator. Under black light illumination, lightly wipe the area in question with the dampened brush or cotton swab. Do not permit solvent to flood or run over the surface of the part. Allow the solvent to evaporate from the surface of the part.

3.4.12.12.3 If an indication reappears immediately and is rejectable to the acceptance criteria, the component may be rejected. If an indication does not appear immediately, apply dry or nonaqueous developer to the area being evaluated. Allow at least 10 minutes for the indication to develop. If no indication reappears, the original indication is considered false. All indications found shall be evaluated to the specified acceptance criteria.

3.4.12.12.4 If necessary, magnification and/or white light may be used to determine the type of discontinuity.

3.4.12.13 Parts exhibiting indications caused by faulty processing, improper cleaning, or excessive background fluorescence shall be cleaned, dried, and reprocessed.

3.4.12.14 Parts with relevant indications shall be withheld pending evaluation in accordance with the OEM's part or material specification or other engineering requirements. When inspections are being performed in conjunction with part manufacturing operations, relevant indications shall be evaluated in accordance with the drawing or other referenced OEM specification(s). Where no defect limits are specified by the OEM or are not given in the maintenance manual, all relevant indications shall be regarded as suspect and shall not be accepted without review by the CEO.

3.4.13 Post-Inspection Cleaning

When required, parts shall be cleaned and dried after inspection to remove inspection residue if detrimental to subsequent operations or where it would impair the structural or functional integrity of the part.

3.5 Responsibility for Inspection

The inspection source shall be responsible for performing all required tests and identifying the parts inspected and accepted.

3.6 Reports

As required by regulatory agency or customer.

4. QUALITY ASSURANCE PROVISIONS

4.1 General

This section contains specific checks to ensure that penetrants, emulsifiers, removers, developers, and equipment meets an acceptable level of quality.

4.1.1 Operators should be alert to any changes in performance, color, odor, consistency, or appearance of powders and fluids and to conduct appropriate checks and tests if they have reason to believe the quality may have deteriorated.

4.2 System Performance Check

4.2.1 This check shall be performed using known and separate defect standards for each sensitivity level of penetrant in use at the facility. The quantity and sizes of the defects in the defect standards(s) shall be capable of demonstrating an unsatisfactory performance of the different penetrant sensitivity levels in use at the facility.

4.2.1.1 It is permissible to use a defect standard, which contains five individual cracks or manufactured indications with each of the cracks or manufactured indications generally appearing as a star burst radiating outward from a localized center. The fluorescent indications produced by the cracks or manufactured indications when using a Level 4 Method D penetrant on the panel shall range in size as shown in Table 1:

TABLE 1 - PANEL INDICATION SIZE

| Indication | Indication Size |
|---|---|
| A | 0.38 to 0.81 mm (0.015 to 0.032 inches) |
| B | 1.17 to 1.57 mm (0.046 to 0.062 inches) |
| C | 1.90 to 2.36 mm (0.075 to 0.093 inches) |
| D | 3.18 to 4.34 mm (0.125 to 0.171 inches) |
| E | 4.57 to 6.35 mm (0.180 to 0.250 inches) |

NOTE: Indication A may appear as a pin point instead of a star burst.

4.2.1.2 It is permissible to use Low Cycle Fatigue (LCF) specimens as defect standards provided the following conditions are met.

4.2.1.2.1 They shall contain multiple cracks having a range in size that will allow the user to discriminate between different sensitivity levels.

4.2.1.2.2 The smallest cracks shall be within the range specified for Crack A in Table 1.

4.2.1.3 If the overhaul facility uses defect standards other than those specified in 4.2.1, then the overhaul facility shall notify the applicable OEM of such and receive a written confirmation of approval prior to using the defect standard(s) to satisfy a Daily System Performance.

4.2.2 Regardless of the defect standard used, a “baseline” for the known defect standard(s) shall be established by processing the known defect standard with unused penetrant materials, using the processing parameters specified within this specification and the following criteria:

4.2.2.1 The baseline shall be established using manual processing or in such a way that complete, uniform application of each material is accomplished at each processing step.

4.2.2.2 Penetrant dwell time shall be recorded for the baseline and used in subsequent comparison runs.

4.2.2.3 Wash/rinse time(s) shall be recorded for the baseline and used in subsequent comparison runs.

4.2.2.4 If applicable, emulsification time shall be recorded for the baseline and used in subsequent comparison runs.

4.2.2.5 Development time and application method shall be recorded for the baseline and used in subsequent comparison runs. Apply developer with the known defect standard in a vertical position or inverted position so as not to have developer application positively influenced by gravity.

4.2.3 A system performance check, of each penetrant sensitivity level in use, shall be accomplished daily, at reactivation of the system after maintenance or repairs, or any time the system is suspected of being out of control.

4.2.3.1 Prior to processing, the defect standard shall be inspected under black light to assure that the defects do not fluoresce because of remaining penetrant or other contamination from prior use. If necessary, the standard shall be recleaned in accordance with 4.2.6.

4.2.3.2 Processing of a known defect standard may be performed concurrently with production parts.

4.2.3.3 The system performance check shall be performed by processing the known defect standard through the facilities penetrant system using the processing parameters used during the initial baseline run.

4.2.3.4 If automated processing is used in any step, the defect standard shall be processed in a position that is considered most detrimental to proper processing. (i.e., In the case of penetrant and developer stations, this should be with the flaw surfaces in a vertical or inverted position and if applicable, with the flaws facing away from any discharge points). The most detrimental position should be established during original equipment set-up by processing the panel through each station in several different orientations and comparing results.

4.2.3.5 The results of the system performance check shall be compared against the recorded “Baseline” results.

4.2.4 When there is a difference in appearance, e.g., size, shape, color, or quantity of indications, between the results of the daily system performance check and the recorded “baseline” results, the in-use materials shall be checked in accordance with the requirements of 4.5.

4.2.4.1 If it is suspected that the defect standard has deteriorated rather than the system, the standard should be recleaned and reprocessed or an alternate defect standard, which has been “Baselined” in accordance with 4.2.2 may be used. Results shall be evaluated per 4.2.5.

4.2.5 Cleaning and Storage of the Defect Standard

To ensure independent, accurate results and to prevent clogging and contamination of the flaws, the known defect standards shall be cleaned and stored in accordance with manufacturer’s recommended instructions or as follows after each run:

4.2.5.1 Remove excess developer. Rinse the defect standard(s) with water using a maximum water pressure of 40 psi and, if necessary, use a soft bristle nonmetallic brush to remove residual developer. Hydro-air nozzles may be used. Blow off residual water spots with an air gun followed by drying the defect standard(s) in a hot air circulating dryer for approximately 20 minutes at a maximum of 71 °C (160 °F).

4.2.5.2 Immerse the cleaned and dried defect standard(s) in a cleaning solvent (e.g., Isopropyl Alcohol, Acetone, or Methyl Ethyl Ketone (where locally approved), etc.) for a minimum of 10 minutes. Remove panel from the cleaner and allow to air dry.

4.2.5.3 Check the defect standard under UV light. If residual penetrant is present, repeat 4.2.6.2 until all evidence of penetrant is removed. Fluorescing indications are all evidence of inadequate cleaning.

4.2.5.4 Store the defect standard in a clean container.

EXCEPTION: It is permissible to allow the defect standard(s) to remain submerged in the cleaning solvent (see 4.2.6.2) until it is ready to be used again. However, assure that the solvent is completely dried on the surface and in the defects of the standard prior to penetrant application. Check per 4.2.6.3 prior to use.

CAUTION: If not cleaned or stored properly, the defect standards may become unusable due to contamination of the flaws.

4.3 Black light

All UV light sources used to inspect parts shall be checked for both UV and visible/white light output using a light meter on at least a daily basis or as necessary to ensure the following output is provided:

4.3.1 Standard handheld black lights shall provide UV output not less than 1000 µW/cm$^2$ and visible/white light not greater than 2 footcandles at 38 cm (15 inches).

4.3.2 Black light borescopes, flexible scopes and UV liquid light guides that are used to inspect parts shall provide UV output not less than 1000 µW/cm$^2$ and visible/white light not greater than 2 footcandles at 3.8 cm (1.5 inches).

4.3.3 UV pen lights that are used to inspect, shall provide UV output not less than 1000 µW/cm$^2$ and visible/white light not greater than 2 footcandles at 1.27 cm (1/2 inch).

4.3.4 All other UV light sources that are used to inspect parts shall provide UV output not less than 1000 µW/cm$^2$ and visible/white light not greater than 2 footcandles at the inspection surface of the part with the light positioned at its typical working distance.

4.3.5 Self-filtered black light bulbs shall not be used unless specified by OEM's procedures.

4.3.6 If the filter glass is dirty, scratched, damaged, or poor fitting so that white light escapes, the condition shall be corrected or the unit replaced.

CAUTION: Unfiltered ultraviolet radiation is hazardous. Black light bulbs shall have suitable filters to eliminate short and medium wavelength ultraviolet radiation.

4.3.7 ASTM E 2297 provides guidance for the use of UV-A and visible light sources and meters.

4.4 Light Meters

4.4.1 Calibrate the light meters (i.e., UV and White light) at frequency specified in Table 2.

4.4.1.1 Light meters shall be calibrated at a minimum of three points over the operating range of typical use. One point shall be near each extreme and one shall be near the mid-range.

4.4.1.2 Meter accuracy for UVA meters should be ±10% at reading or 50 Microwatts/cm$^2$, whichever is greater.

4.4.1.3 Meter accuracy in white light meters should be ±10% at reading or ±0.5 fc, whichever is greater.

4.5 Fluorescent Penetrant Materials (Methods A, B, C, and D)

4.5.1 Penetrant

4.5.1.1 Non-water based, water washable penetrants (Method A) in immersion or recirculating tanks shall be checked for water content monthly in accordance with ASTM E 1417.

4.5.1.1.1 Penetrants shall be discarded if the water content of the in-use penetrant is in excess of 5% by volume of the original penetrant or when it can't be adjusted either by adding new penetrant or by using a procedure approved by the manufacturer of the penetrant to provide a water content level of less than 5%, when tested in accordance with ASTM E 1417.

4.5.1.2 Water-based, water washable penetrants (Method A), in immersion or recirculating tanks shall be checked with a refractometer weekly for water content.

4.5.1.2.1 Penetrant shall be discarded if the water content exceeds the percentage of water specified in QPL-AMS-2644 for the specific, penetrant manufacturers material, or when it can't be adjusted to the specified water content.

4.5.1.3 Fluorescent brightness shall be determined per ASTM 1135 in accordance with Table 2.

EXCEPTION: If new penetrant can be added to the tank to make it acceptable, or if the fluorescent brightness is acceptable to the "Penetrant Brightness" requirements of ASTM E 1417, the in use penetrant can continue to be used.

4.5.2 Hydrophilic Emulsifier

Check emulsifier in immersion tanks weekly for penetrant contamination. If emulsifier bath has penetrant floating on the surface or adhering to the sides of the tank, the bath shall be discarded. After discarding the contaminated emulsifier, clean the tank before adding fresh emulsifier.

4.5.2.1 Using a refractometer, check concentration of emulsifier (dip tank and spray) weekly and after replenishing, and correct as necessary. Refractometer value shall be in accordance with the material manufacturer's specification. If there is an unexplained increase in background fluorescence, recheck emulsifier concentration.

4.5.2.2 For immersion application, the concentration of emulsifier shall be no higher than the manufacturer's qualified (approved) concentration as specified in QPL-AMS-2644. Concentration shall be controlled to ±3% of the initial concentration or the nominal value selected.

4.5.2.3 Emulsifier spray concentrations shall not exceed 5%.

4.5.3 Lipophilic Emulsifier

Check for penetrant contamination of emulsifier monthly and after replenishing. Compare a sample from the tank with a sample of unused emulsifier for emulsifying ability. Discard emulsifier in tank when its emulsifying ability is less than that of the unused material.

4.5.3.1 Check for water contamination of emulsifier monthly in accordance with ASTM E 1417. Water content in excess of 5% is unsatisfactory.

4.5.3.2 After discarding contaminated emulsifier, clean tank before adding fresh emulsifier.

4.5.4 Replenishment

Add fresh penetrant and emulsifiers when necessary. The contents of fresh containers shall be near shop (room) temperature and thoroughly mixed with in-use materials.

4.6 Operating Pressures and Temperatures

Verify indicators and controllers daily as to setting and calibrate every 6 months. Indicators shall be accurate to within ±5% of their reading within the range they are used.

4.6.1 A temperature uniformity check in at least five different locations within the dryer shall be conducted every 6 months to assure that areas of the dryer do not exceed 71 °C (160 °F). Four of the locations shall be equally spaced around the perimeter of the dryer and one location shall be near the center of the dryer.

4.7 Dry Developing Powders

4.7.1 Check dry developer daily to ensure it is fluffy and not caked. Discard if it is caked (See 7.2.7).

4.7.2 Check recycled dry developer daily for contamination by forming a thin layer approximately 100 mm (4 inches) in diameter on a paper towel and examine under black light. Discard developer if ten or more fluorescent specks appear.

4.7.3 Check automated developing system daily to ensure it is working properly and guns are not clogged.

4.8 Water Soluble/Suspendible Developers

4.8.1 Check concentration in dip tanks initially and at least weekly with a hydrometer. Specific gravity shall be in accordance with manufacturer's specification.

4.8.2 Scan the surface of developer weekly with a black light for indications of fluorescence. Immerse a clean aluminum panel approximately 75 x 250 mm (3 x 10 inches) in the developer and remove for drying and inspection under black light for indications of fluorescence and surface wetting. Replace developer when fluorescence is detected.

4.8.3 Check developer daily for scum on the surface or inability to completely wet the surface of parts being inspected. Replace the developer if any of these conditions is evident.

4.8.3.1 If contaminated developer is discarded, ensure tank is cleaned before adding fresh developer.

4.9 Inspection Booth

With curtains drawn, check ambient white light in the booth at the working surface at least monthly using a white light meter (See 3.4.12.2). Confirm daily cleanliness of the work area and absence of fluorescent contamination, which may contaminate parts or degrade the inspection.

4.10 Timers

All timers used to control the process shall have an accuracy of ±10% of setting. This includes automatic pre-set stage timers in manual and automatic lines. . Timing devices used to measure or monitor processing times, such as dwell times and eye adaptation times, need not be calibrated. Mechanical timers shall not be used to measure or monitor the process.

4.11 Tank Cleaning

All tanks shall be monitored and cleaned as necessary to prevent the build up of corrosive elements and impurities which could contaminate components lowered into the tank bottom.

4.12 Material Storage

Properly store and legibly identify all materials in accordance with the material manufacturer recommendations.

4.13 Test Intervals

The frequency of required material and equipment checks are specified in Table 2.

TABLE 2

| Description | Frequency | Applicable Paragraph |
|---|---|---|
| System performance check | Daily, or prior to use | 4.2 |
| Black light* | Daily, or prior to use | 4.3 |
| Black light meter calibration* | 6-month intervals | 4.4 |
| White light meter calibration* | 6-month intervals | 4.4 |
| Water content (non-water based, water washable penetrant) | Monthly | 4.5.1.1 |
| Water content (water-based, water washable penetrant) | Weekly | 4.5.1.2 |
| Penetrant brightness | Quarterly | 4.5.1.3 |
| Hydrophilic remover contamination | Weekly | 4.5.2.1 |
| Hydrophilic emulsifier concentration* | Weekly | 4.5.2.1, 4.5.2.2, 4.5.2.3 |
| Lipophilic emulsifier contamination* | Monthly and after replenishment | 4.5.3 |
| Pressure and temperature controls* | Verified daily and 6-month calibration | 4.7 |
| Dryers/Ovens | 6-month intervals | 4.7.1 |
| Dry developer* | Daily for caking and for contamination of recycled developer | 4.8 |
| Water soluble/Suspendable developer | Concentration initially and weekly<br>Weekly for fluorescence<br>Daily for scum | 4.9 |
| Inspection booth, ambient white light, and fluorescent contamination* | Monthly for ambient white light and daily for contamination | 3.4.12.2 and 4.10 |

*The maximum time between verifications or checks may be extended when substantiated by technical data and approved by the CEO.



5. ACKNOWLEDGMENT

A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

6. REJECTIONS

Acceptance/rejection criteria shall be as specified by the OEM or other CEO.

7. NOTES

7.1 A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

7.2 Terms used in AMS are clarified in ARP1917 and as follows:

7.2.1 Angstrom

A unit of length formerly used to express wavelength of electromagnetic radiation. One angstrom equals 0.1 nanometer.

7.2.2 Background

The surface of the part upon which the indication is viewed. It may be either the natural surface of the test part or the developer coating on the surface.

7.2.3 Background Fluorescence

Fluorescent residues observed over the general surface of the test part. Local areas of background fluorescence are generally caused by improper penetrant removal or surface contamination. Such contamination, if present, can interfere with the visibility of defect indications.

7.2.4 Black Light

Electromagnetic radiation in the near ultraviolet range (UV-A) of wavelength 3200 to 4000 Angstrom units (320 to 400 nm). See also, Ultraviolet Light 7.2.61.

7.2.5 Black Light Filter

See Filter 7.2.34.

7.2.6 Black Light Meter

A meter containing photo sensitive cells for reading of black light intensity in microwatts per square centimeter ($\mu W/cm^2$).

7.2.7 Caked

A semi-solid condition of dry developer caused by moisture or other liquid contaminants.

7.2.8 Capillary Action

The tendency of certain liquids to travel, climb, or draw into tight crack-like interface areas due to such properties as surface tension, wetting, cohesion, and adhesion.

7.2.9 Cognizant Engineering Organization (CEO)

The company, agency, or other authority responsible for the design or delivery, and the end use of the system or component for which liquid penetrant examination is required. This in addition to design personnel may include personnel from material and process engineering, stress analysis, NDT or quality groups, as appropriate.

7.2.10 Contact Time

The total time between application and removal of the penetrant or emulsifier or remover, or both.

7.2.11 Contaminants

Any material or material residue which interferes with entry of the penetrant into surface discontinuities. Also pertains to material left on the surface of the part because of improper cleaning and retained residual penetrant. Can also mean undesired materials in the penetrant, emulsifier, and remover, which affect their performance

7.2.12 Daily

Each day that the system is in use.

7.2.13 Dark Adaptation

The adjustment of the eyes, which commences when one passes from a bright to a darkened place.

7.2.14 Defect

Discontinuity, which exceeds specified acceptance criteria.

7.2.15 Degreasing

A cleaning method using solvents or cleaners employed to remove oil and grease from the surface of the part before the penetrant is applied.

7.2.16 Developer

A material that is applied to the test part surface after the excess penetrant has been removed and that is designed to enhance the penetrant bleedout to form indications. The developer may be a fine dry powder, or a suspension (in solvent or water) that dries leaving an absorbent film on the test part surface.

7.2.17 Developer, Dry

A dry, fine powder that is applied as a dust to the test part after the excess penetrant is removed and the surface dried.

7.2.18 Developer, Nonaqueous Wet (NAWD)

A developer consisting of fine particles suspended in a volatile solvent which is applied by spraying onto the test part surface after the excess penetrant is removed and the surface dried.

7.2.19 Developer, Soluble

A material completely soluble in its carrier (usually water) which dries to an absorbent coating. It is applied to the part after removal of the excess penetrant and prior to drying.

7.2.20 Developing Time

The elapsed time between the application of dry developer or NAWD and the examination of the part for indications. Also the elapsed time between removal of the part from the dryer and the examination when using water-soluble developer.

7.2.21 Discontinuity

Any interruption in the normal physical structure or configuration of a part, such as cracks, laps, seams, inclusions, or porosity. A discontinuity may or may not be a relevant defect.

7.2.22 Drain Time

That portion of the contact or dwell time during which the excess penetrant, emulsifier, or remover drains off the test piece.

7.2.23 Drying Oven

A low temperature oven used for drying rinse water from the test part or to hasten drying of aqueous wet developer.

7.2.24 Drying Time

The time required for a rinsed or wet-developed part to dry.

7.2.25 Dwell Time

The total time that a penetrant, emulsifier, remover, or developer spends in contact with the component. For aqueous and nonaqueous developers, the dwell time starts after the developer is dry on the component.

7.2.26 Emulsifier

A liquid that interacts with an oily penetrant to make it water washable.

7.2.27 Emulsification Time

The total time that an emulsifier is permitted to combine with the penetrant prior to removal by water.

7.2.28 Engine Parts

Disassembled turbine or reciprocating engine parts or components.

7.2.29 Major Rotating Components

A rotating part whose life is governed by low cycle fatigue limits or other mechanical property limits. (Examples: disks, shafts, spools, hubs, spacers, seals as defined in 7.2.55.)

7.2.30 Etching

A process for the controlled removal of surface material by chemical agents. May be used to remove smeared metal caused by intentional or adventitious cold working.

7.2.31 Evaluation

A process of determining the severity of the condition after a penetrant indication has been interpreted. Evaluation leads to determining whether the part is acceptable, salvageable, or rejectable.

7.2.32 False Indication

A penetrant indication that might be erroneously interpreted as a defect or discontinuity in the test part.

7.2.33 Family

The complete series of compatible materials from one manufacturer designed to perform a specific process of penetrant inspection.

7.2.34 Filter

Used in conjunction with a mercury vapor lamp to suppress visible and harmful short-wavelength ultraviolet radiation and to transmit near ultraviolet radiation.

7.2.35 Flaw

An imperfection in a part or material which may or may not be relevant to the function of the part.

7.2.36 Fluorescence

The emission of light (usually yellow-green) by fluorescent penetrant as the result of, and only during, irradiation by ultraviolet light.

7.2.37 Fluorescent Contamination

Contamination of parts or developer with fluorescent penetrant. Also, contamination of the inspection area.

7.2.38 Foot-candle

The illumination on a surface, 0.09 $m^2$ (1 square foot) in area, on which is uniformly distributed a flux of 2 lm (lumen). It equals 10.8 $lm/m^2$ or 0.09 lx.

7.2.39 Hydrophilic Emulsifier

A water soluble detergent concentrate used with the post-emulsifiable penetrants.

7.2.40 Indication (Penetrant)

The visible evidence of penetrant fluorescence indicating to the inspector that some sort of surface anomaly may be present. Indications may be either false or valid, or may be relevant or nonrelevant.

7.2.41 Inspection

Visual examination of test parts, using black light, after completion of the penetrant processing steps.

7.2.42 Interpretation

The determination of the significance of the indications from the standpoint of whether they are relevant or nonrelevant.

7.2.43 Known Defect Test Standard

A test standard containing known defects used to perform system performance checks.

7.2.44 Lipophilic Emulsifier

A ready to use oil base emulsifier which is miscible with penetrant. The resulting mixture of the two oils is easily emulsified under a water spray.

7.2.45 Micro (μ)

A prefix that indicates one millionth ($10^{-6}$).

7.2.46 μ W/cm2

Microwatts per square centimeter. Units used in measurement of short wavelength energy.

7.2.47 Nonrelevant Indication

A penetrant indication that is not or cannot be associated with a discontinuity.

7.2.48 Part or Material Specifications

A specification provided by the OEM in the form of manuals, drawings or other documents that instruct the user in the maintenance and handling of specific parts or components.

7.2.49 Penetrant

A liquid capable of entering discontinuities or defects open to the surface and which is adapted to the inspection process by being highly visible in small traces.

7.2.50 Penetrant, Fluorescent

An inspection penetrant that is characterized by its ability to fluoresce when excited by black light.

7.2.51 Penetrant, Post-Emulsifiable

A penetrant that requires the application of a separate emulsifier to render the surface penetrant water-washable.

7.2.52 Penetrant, Water-Washable

A penetrant with built-in emulsifier which makes it directly water-washable.

7.2.53 Post-Inspection Cleaning

The removal of penetrant material residues and developer from the test part after the penetrant inspection process is completed.

7.2.54 Precleaning

The removal of surface contaminant from the test part so that it cannot interfere with the penetrant inspection process.

7.2.55 Prime Reliable Part (PRP)

Disks, rotors, hubs shafts, major rotating seals and spacers, etc. which function within an engine. Failure of these parts may cause substantial damage and could potentially result in an uncontained failure and possible loss of an aircraft.

7.2.56 Refractometer

A device that measures the refractive index of a liquid. This value increases in proportion to the dissolved solids in the liquid, and hence has been used to measure hydrophilic remover concentration.

7.2.57 Relevant Indication

An indication caused by a discontinuity.

7.2.58 Rinse

The process of removing liquid penetrant inspection materials from the surface of the test part by either immersion in an agitated water tank or vigorous spraying with water. Also termed “wash”

7.2.59 Sensitivity

The ability of a penetrant system to indicate the presence of a surface-connected discontinuity. The three categories of penetrant materials, i.e., medium, high, ultra high, as determined by known defect standards.

7.2.60 Specific Gravity

The ratio of the density of a substance (usually aqueous developer) to the density of water usually measured at 15.6 °C (60 °F).

7.2.61 Ultraviolet Light (UV)

The term applied for radiation below the visible range. As used in fluorescent penetrant inspection between 3200 and 4000 Angstrom units (320 and 400 nm). See also, black light 7.2.4.

7.2.62 Viscosity

The state or degree of being viscous, i.e., the resistance of a fluid to flow, for example, through a restricted orifice.

7.2.63 Water Content

The percentage of water contamination of a sample of water washable penetrant or lipophilic emulsifier taken from the process tanks.

7.2.64 White Light Meter

A meter that will measure white light in foot-candles or lux.

7.3 Dimensions in SI units and the Celsius temperatures are primary; dimensions and properties in inch/pound units and the Fahrenheit temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

7.3.1 Units without parentheses are primary due to normal usage.

7.4 Purchase documents should specify not less than:

AMS2647C

PREPARED BY AMS COMMITTEE “K”

## APPENDIX A - GUIDELINES FOR DESIGN, PROCUREMENT AND/OR FABRICATION OF PENETRANT INSPECTION EQUIPMENT

A.1 Part handling systems should be available and should have the following features:

A.1.1 Construction so as not to cause damage or contamination of the part and not to cause or obscure indications.

A.1.2 Construction of handling systems should minimize contamination of penetrant materials.

A.1.3 Part handling systems should allow easy manipulation of the part to assure complete application and removal of penetrant materials and draining of excess fluids to minimize “drag-out” and contamination of subsequent processing tanks.

A.1.4 Part handling systems should minimize handling of the parts after penetrant removal to reduce the risk of part contamination and/or smearing or obliteration of indications. Fixtures should be used when available to minimize handling of the part by the processor as well as to assist with positioning so as to allow adequate lighting and systematic scanning of the part surface during inspection.

A.2 Tanks for processing materials should have the following features:

A.2.1 Construction from non-corrosive materials.

A.2.2 Drain racks or drain stations and splash guards to prevent contamination of adjacent tanks.

A.2.3 Covers to protect contents when not in use.

A.2.4 Identification sign for the material in each tank.

A.3 Spray booths for penetrant, emulsifier and developer operations should have the following features:

A.3.1 Adequate exhaust provisions to prevent breathing of excessive vapors or dust by operators and accumulation of flammable penetrant mists.

A.3.2 Construction that will minimize contamination of adjacent process materials or parts.

A.3.3 Some means of easily identifying the material dispensed from each spray nozzle.

A.3.4 Dry developer containers should have some method of assuring that developer remains dry and fluffy during daily use. Shakers, stirrers and heaters should be used as necessary.

A.3.5 Aqueous developer containers should have some method of assuring that developer is maintained at appropriate suspension/concentration during daily use.

A.4 Water systems for rinse operations should have the following features:

A.4.1 Controls and temperature gauges to maintain water temperature and pressure within the limits specified in this document. Gauges should be clearly identified (i.e., rinse water pressure, rinse water temperature, etc.) and be located so that they are easily viewable by personnel processing parts.

A.4.2 Hose and spray nozzle that delivers water in a cone or fan shaped spray pattern consisting of relatively coarse droplets (as opposed to a narrow stream or fine spray). Air augmented or Hydro-air nozzles may be used within the limits specified in this document.

A.5 Circulation hot air dryer or ovens, if used should have:

A.5.1 Controls and temperature gauge to regulate the temperature up to the maximum temperature limit specified in this document. Temperature gauges should be located so that they are clearly viewable by personnel processing parts.

A.5.2 A clean, dry, regulated compressed air supply should be available that does not contaminate parts or inspection materials. Air supplies may be tested as follows:

Air line cleanliness should be checked by directing the air stream onto a sheet of white filter paper or clean glass mirror (2 inch square or round or larger). Prior to testing, allow the compressed air system to reach operating pressure, and allow air in the compressed air system to discharge at operating conditions to remove accumulated condensation in the system. Position the filter paper or mirror eight to ten inches from the air discharge point, perpendicular to and centered in the air stream. Fully open the discharge valve for 15 to 20 seconds. If any fouling of the paper is evident, the line should not be used until the cause is ascertained and corrected. All moisture traps should be checked periodically, and if found full, emptied before the line is used.

A.6 Timing systems should have the following features:

A.6.1 Appropriate resolution for the process step.

A.6.2 Clearly visible and/or have a clearly audible alarm that signals the end of the timing cycle.

A.6.3 Where multiple components or batches of components are processed through a line in overlapping intervals, separate timers or recorded start and stop times should be used for each component or clearly-marked batch of components to ensure proper processing times.

A.7 Inspection booths should have the following features:

A.7.1 Visible light levels within the limits specified in this document. Construction should be so as to prevent light leaks from being within the inspector's line of sight while performing part inspection.

A.7.2 Inspection table tops that are black or dark in color and have a non-metallic low or non-reflective finish that allows easy removal of residual penetrant materials.

A.7.3 Fixtures should be provided which enable easy manipulation of the UV light and/or part to provide for full inspection coverage.

## APPENDIX B - GUIDELINES FOR ASSESSMENT OF BACKGROUND FLUORESCENCE

B.1 Properly cleaned and processed parts should generally exhibit minimal levels of background fluorescence. Parts exhibiting no background could indicate over emulsification and/or over washing of the part which could result in reduced sensitivity while parts exhibiting high levels of background could indicate improper cleaning which could prevent penetrant from entering flaws. Increased background also results in reduced contrast between defect indications and surrounding areas, also reducing inspection sensitivity.

B.2 No quantitative means currently exists for assessing background fluorescence levels and therefore no hard and fast rules can be applied when determining whether the amount of background fluorescence is acceptable. There is no substitute for experience based good judgment and common sense when determining whether the level of background fluorescence on a part is acceptable. The information provided below is to be used as a guideline since it is not possible to address all situations that may be encountered.

B.3 Parts exhibiting appreciable levels of background fluorescence should be examined under white light to help determine the probable cause of the background. There are three primary causes of background fluorescence, as follows:

B.3.1 Background fluorescence caused by surface coatings - Checking internal or mating surfaces of parts, where the coating may be worn or absent, can aid in determining whether this is the cause of the background.

B.3.2 Background fluorescence caused by part surface finish - Background caused by this condition will typically be fairly uniform over the entire part surface or common, geometrically similar areas of the part surface and may be visually apparent. However, excess background may also be due to local rework or in-service wear in which case the background will typically be confined to localized areas of the part.

B.3.3 Background fluorescence caused by surface contaminants – Surface contaminants can occur from service use. Visual evidence of contaminants and/or use of locally applied cleaning agents or mild abrasives can aid in determining if this is the cause of the background. If using localized cleaning to determine the presence of surface contaminants, care should be exercised when using any cleaning agent or abrasive to avoid contaminating or closing the crack. This localized cleaning should only be done in non-critical areas when allowed by the OEM manual and/or local operating procedures. Local etching may be required if abrasives are used and allowed by the OEM. If surface contamination is found, the part should be re-cleaned and reprocessed.

B.4 After determining the cause of the background, use the following guidance to determine appropriate disposition.

B.4.1 Background fluorescence due to surface coatings is acceptable providing pre-inspection requirements do not specify removal of the coating. However, if the area exhibiting background is adjacent to a critical area and/or could interfere with inspection of other surfaces, the background shall be reduced to an acceptable level. One method of achieving this would be to mask the offending area to prevent illumination with the UV light.

B.4.2 Light to moderate background fluorescence due to normal part surface finish is generally acceptable. This type of background is to be expected on cast parts, porous materials or parts with rough finishes caused by manufacturing operations. Close attention during the penetrant removal step will help hold this type of background to a minimum. Maximum emulsification and wash times should be used if background fluorescence due to surface finish is thought to be a problem.

B.4.3 Background fluorescence due to abnormal part surface finish, such as that caused by erosion, corrosion, chemical etching, in service wear or fretting, improper rework, etc., may or may not be acceptable. If the condition is due to normal in service wear and in itself is not cause for rejection of the part, then the background is to be expected and is typically acceptable. When the condition is questionable, especially if located on a critical area of the part, the cognizant engineering organization (CEO) should be consulted to make this determination.

B.4.4 Background fluorescence caused by surface contamination also may or may not be acceptable. Parts exhibiting background that is thought to be caused by surface contaminants should be re-cleaned if allowed by the manual. The second cleaning operation should be coordinated with the cleaning organization to identify areas requiring special attention and/or an alternate cleaning process.

B.5 If the cause for background fluorescence cannot be determined and/or if its acceptability is uncertain the following general rules may be used to help with determining a disposition:

B.5.1 Critical rotating engine hardware should have little or no background fluorescence (see definition in 7.2.3). At no time is excessive background fluorescence permitted on disk, hub or drum rotor bores, or on fore and aft surfaces adjacent to these bores.

B.5.2 Low to moderate background fluorescence on other components is acceptable, however, high stress or critical locations shall be closely examined and questionable indications shall be evaluated using magnification and/or other inspection methods. The solvent wipe process can also be used but shall be applied with caution and should not be repeated more than once. If necessary, a local FPI of the area can be repeated to determine if the indication is repeatable.

B.6 If, in the judgment of the inspector, the level of background fluorescence prevents reliable detection of defects or, if due to the critical nature of the part, airworthiness may be jeopardized, the CEO should be contacted for further instruction.

B.6.1 Parts with recurrent cleaning problems should be brought to the attention of the CEO to determine possible alternate actions.

## APPENDIX C - PROCESSING AND INSPECTION OF DRUM ROTORS/DEEP WELL SPOOLS AND OTHER COMPLEX PARTS W/LIMITED ACCESSIBILITY

C.1 When invoked by the CEO, the objective of this appendix is to provide general requirements for performing a reliable fluorescent penetrant inspection (fpi) on the internal cavities of drum rotors/deep well spools and other parts with limited accessibility.

C.2 This appendix provides general instructions for processing parts as well as a performance specification to qualify the viewing system that will be utilized during inspection.

C.3 The requirements contained in this appendix are intended to augment the requirements within this document and to serve as a baseline for processing parts with complex geometry. These instructions do not supersede any specific inspection requirements defined by the CEO.

C.4 GENERAL REQUIREMENTS

C.4.1 Detailed written instructions shall be established for each part and shall include the following information:

C.4.1.1 Applicability including part description and part number.

C.4.1.2 Any specialized tooling to allow for part manipulation for processing and inspection.

C.4.1.3 Instructions for proper application of the tooling.

C.4.1.4 Method for removing excess fluid from internal cavities.

C.4.1.5 Method for assuring complete penetrant coverage.

C.4.1.6 Method for assuring adequate control of penetrant removal.

C.4.1.7 Method for assuring complete developer coverage.

C.4.1.8 Definition of areas requiring inspection.

C.4.1.9 Method for applying inspection equipment such that inspections are accomplished in a controlled manner which provides for complete inspection coverage.

C.5 SPECIAL TOOLS AND EQUIPMENT

C.5.1 Tooling to support and rotate parts during penetrant processing and inspection.

C.5.1.1 Fixtures shall allow easy rotation and manipulation of the component during all stages of penetrant processing including penetrant application, rinsing, washing, and draining.

C.5.1.2 Parts will often require rotation around more than one axis to allow for both complete coverage and adequate draining of cavities. More than one fixture may be necessary.

C.5.2 Suction systems (pump or siphon) to efficiently remove excess liquids from cavities.

C.5.3 Supplemental dry developer application systems to assure application of dry developer inside cavities. Dust cabinets are typically not adequate.

C.5.4 Black light/white light systems capable of accessing cavities between webs, such as UV light source with liquid light guide.